

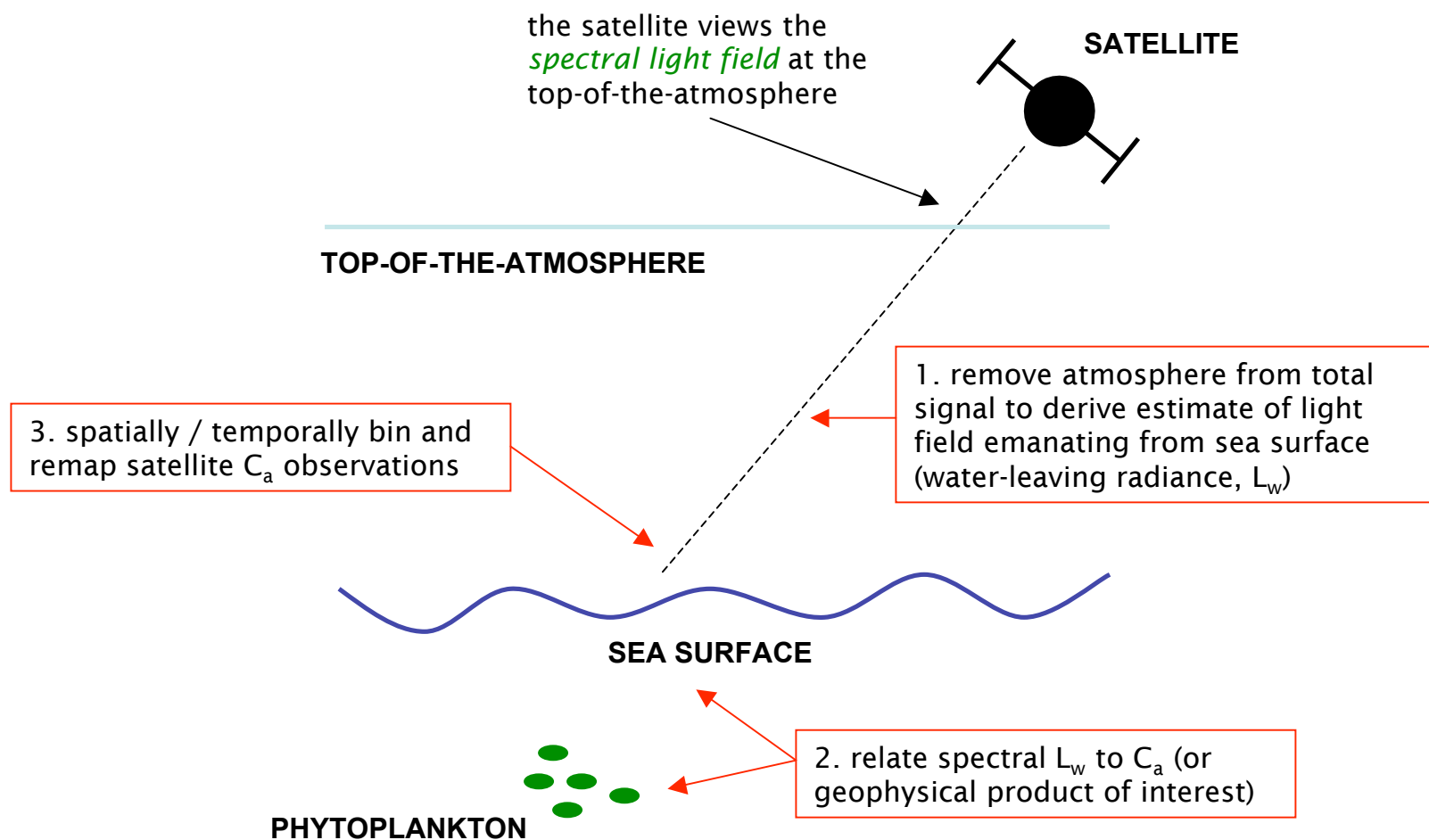
Long-term spatial and temporal evaluation of chlorophyll from SeaWiFS and MODIS-Aqua in Chesapeake Bay

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background



PROCESSING

6,200 SeaWiFS files acquired
3,000 MODIS-Aqua files acquired
launch (Sep 1997, Jun 2002) to Mar 2007
statistical QC applied
9 days / month for both sensors retained

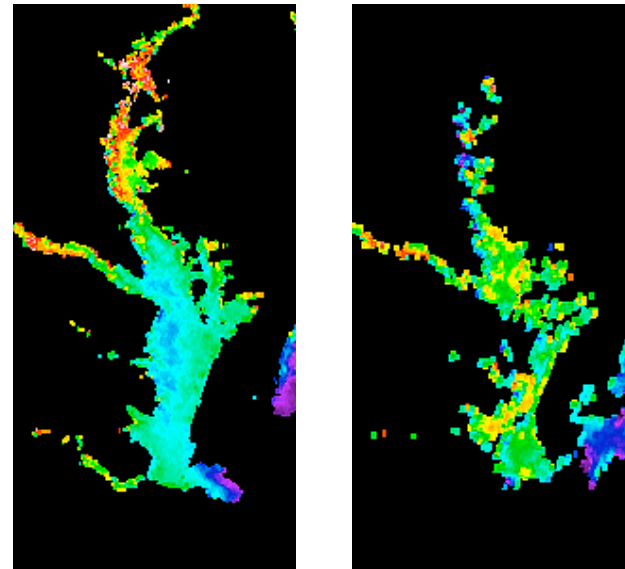
CONFIGURATION

reprocessing 5.2 for SeaWiFS (Jul 2007)
reprocessing 1.1 for MODIS-Aqua (Aug 2005)
updated vicarious gains
updated out-of-band correction coefficients
version 5 of OC3 and OC4

STRATIFICATION

spatially: upper, middle and lower Bay
temporally: Winter, Spring, Summer, Fall

QUALITY CONTROL



GOOD

BAD

eliminate scenes with high sat zenith
require >25% of Bay ocean pixels to be cloud free
visual inspection
consider only $0.001 < C_a < 100 \text{ mg m}^{-3}$
require >200 valid pixels per scene

ALGORITHMS

empirical (statistical) approaches

OC4	operational SeaWiFS
OC3	operational MODIS
OC-Clark	tuned to Bay (NOAA)
OC-spie	tuned to Bay (OBPG)
OC-corr	tuned to Bay (OBPG)
OC-sat	tuned to Bay (OBPG)

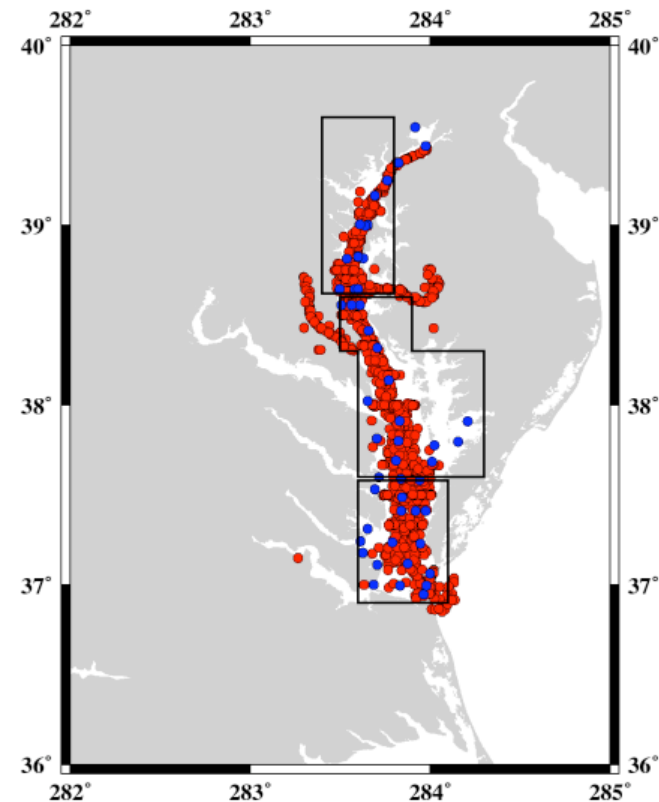
semi-analytical approaches

GSM-CB	tuned to Bay (UMD)
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STRATIFICATION

spatially: upper, middle and lower Bay
temporally: Winter, Spring, Summer, Fall
follows Magnuson et al. 2004

GROUND TRUTH

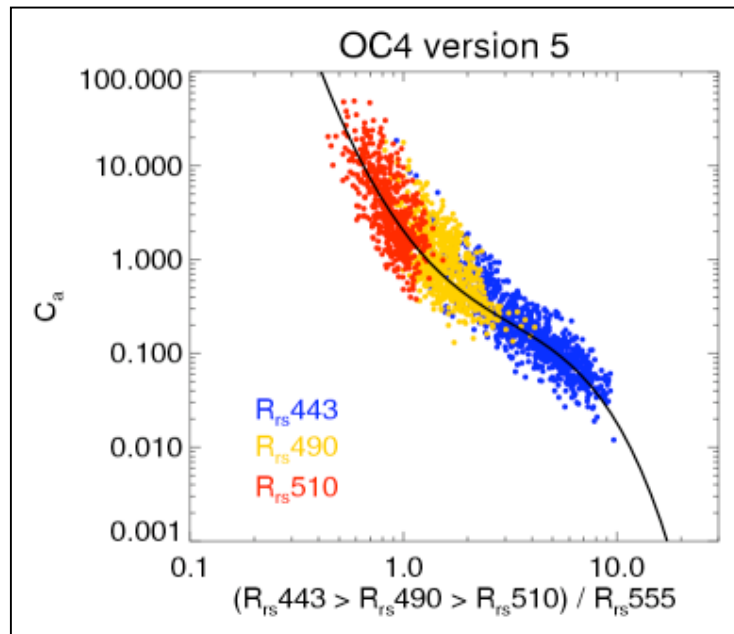


SIMBIOS/Harding (3,000 stations)

CBP (15,000 stations)

through 2005

empirical algorithms



**assume covariance of C_a and
all other optically significant
water column constituents**

only require 490 - 555

general form of algorithm

$$\log_{10}(C_a) = (c_0 + c_1 R + c_2 R^2 + c_3 R^3 + c_4 R^4)$$

where R is $\log_{10}(R_{rs}[\text{blue}] / R_{rs}[\text{green}])$

wavelengths used

OC4 = 443 > 490 > 510 / 555

OC3 = 443 > 490 / 555

OC-Clark = (443 + 490) / 555

OC-spie = 443 > 490 / 555

OC-sat = 443 > 490 / 555

principle differences

development data set (R_{rs} and C_a)

coefficients / regression

semi-analytical algorithms

$$R_{rs} = g_0 \left(\frac{b_b}{a + b_b} \right) + g_1 \left(\frac{b_b}{a + b_b} \right)^2$$

simplification of the radiative transfer equation

a == absorption coefficient

b_b == backscattering coefficient

g == constant

a separated into contributions by:

water (w) , dissolved + non-algal detrital material (dg), and phytoplankton (ϕ)

b_b separated into contributions by:

water (w), and particles (p)

require all λ to be viable & *a priori* assumptions about constituents

analyses

metrics for algorithm evaluation

frequency distributions

relative % difference (RPD) in median of distribution

relative % difference (SPD) in width of distribution [via SIQR of $\log_{10}(C_a)$]

time-series

relative % difference (RPD) in monthly medians

level-2 match-ups

ratio of satellite-to-in situ measurement

absolute % difference (APD) between satellite and in situ measurement

coverage

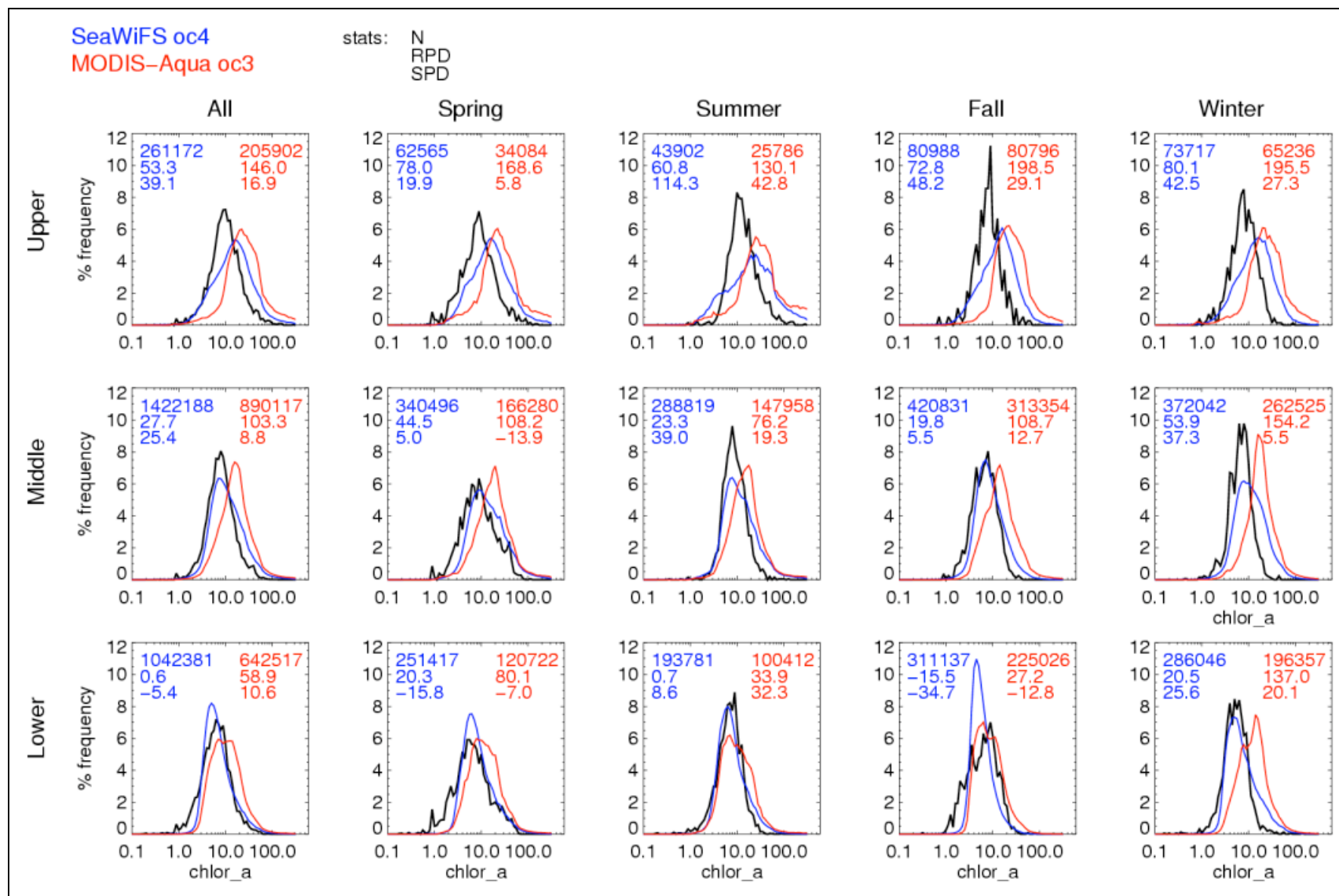
samples sizes of three above analyses (# pixels with $0.001 < C_a < 100 \text{ mg m}^{-3}$)

$$APD = 100\% \times \left| \frac{C_a^{satellite}}{C_a^{in situ}} - 1 \right| \quad RPD = 100\% \times \left(\frac{C_a^{satellite}}{C_a^{in situ}} - 1 \right) \quad Ratio = \frac{C_a^{satellite}}{C_a^{in situ}}$$

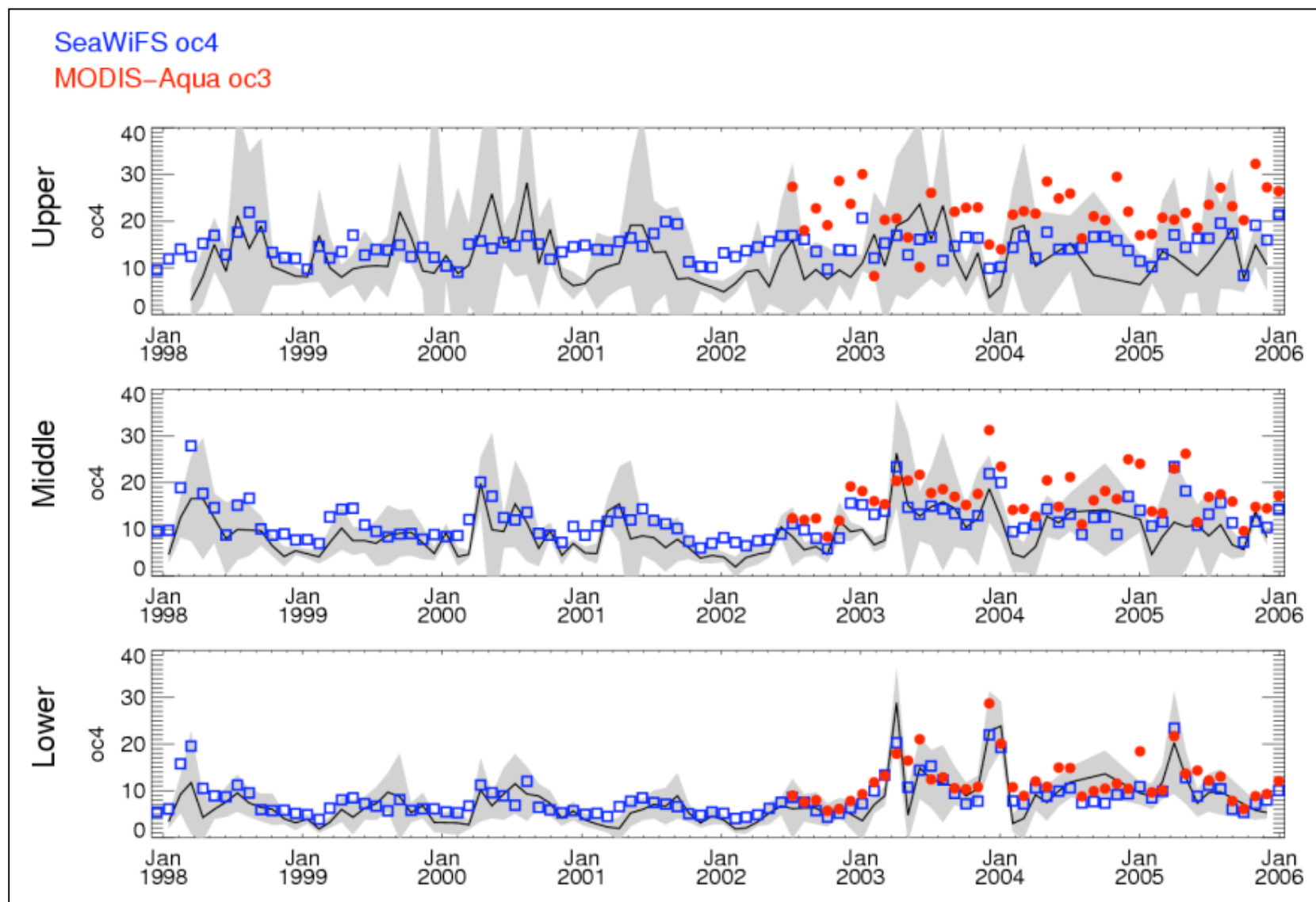
$$SPD = 100\% \times \left[\exp(SIQR^{satellite} - SIQR^{in situ}) - 1 \right]$$

semi-interquartile range (SIQR)
~ distance b/w 25th and 75th quartile

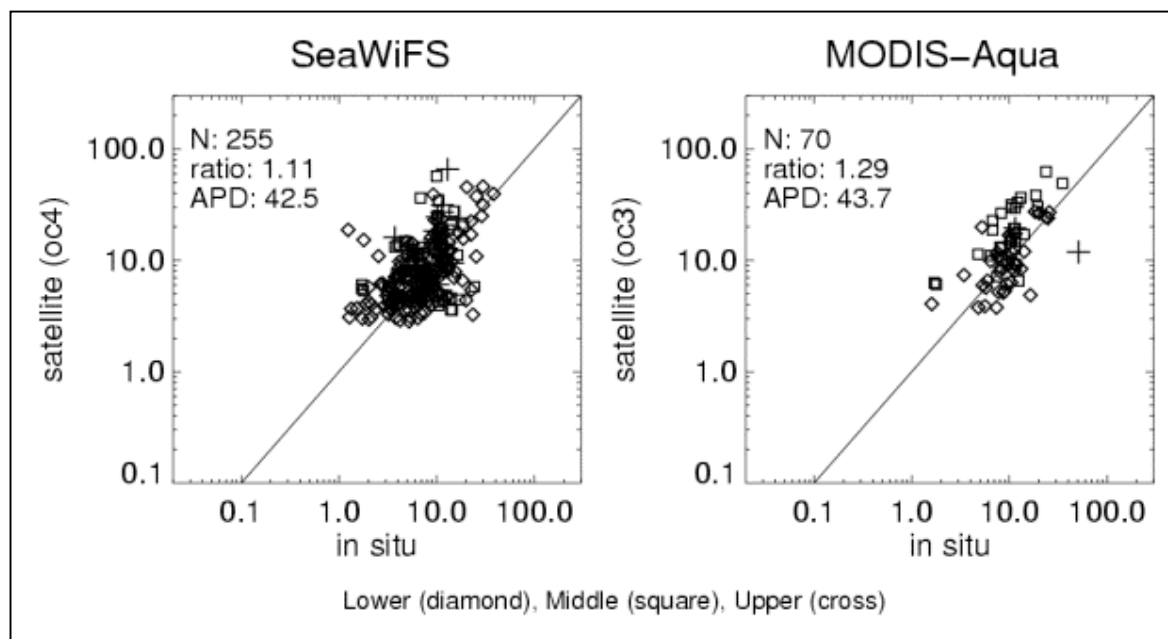
frequency distributions



time-series

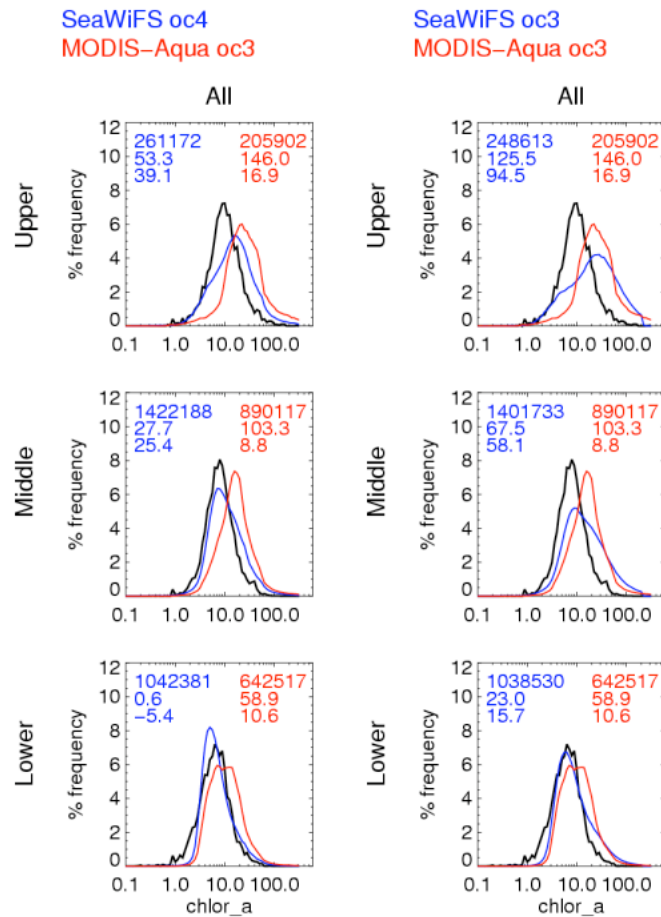


level-2 satellite-to-in situ match-ups



results posted at http://seabass.gsfc.nasa.gov/eval/cbp_v2.cgi

lessons learned



OC4 outperforms OC3

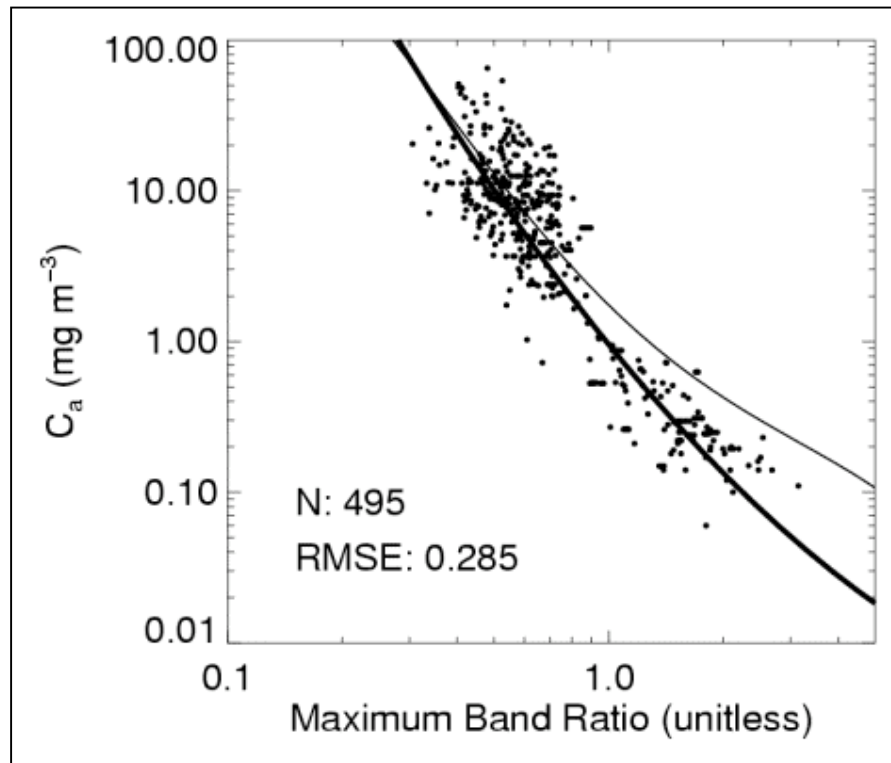
**indicates the utility of $R_{rs}(510)$
for remote sensing of Bay**

510-nm not available
on MODIS-Aqua or -Terra
(531-nm not useful for OC)

510-nm not be available on NPP-VIIRS

known differences between
SeaWiFS OC4 and MODIS-Aqua OC3

OC-spie is tuned to in situ R_{rs} and C_a pairs collected in Chesapeake Bay

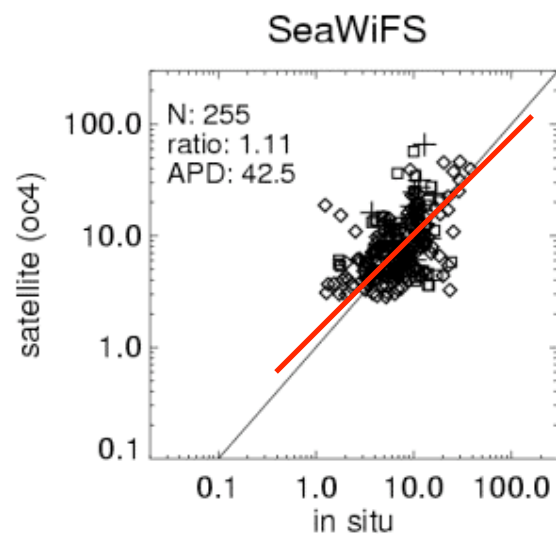


OC3 analog (443,490,555-nm)

thick line: OC3-spie

thin line: OC3 (operational)

ODU proposed similar approach
for 2006 Round Robin

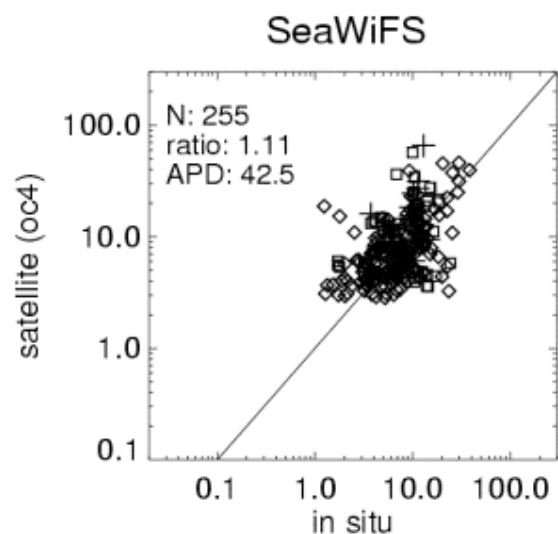


OC-corr borrows from

K.J.W. Hyde, J.E. O'Reilly, and C.A. Oviatt,
 "Validation of SeaWiFS chlorophyll a in
 Massachusetts Bay," Cont. Shelf Res. 27,
 1677-1691 (2007).

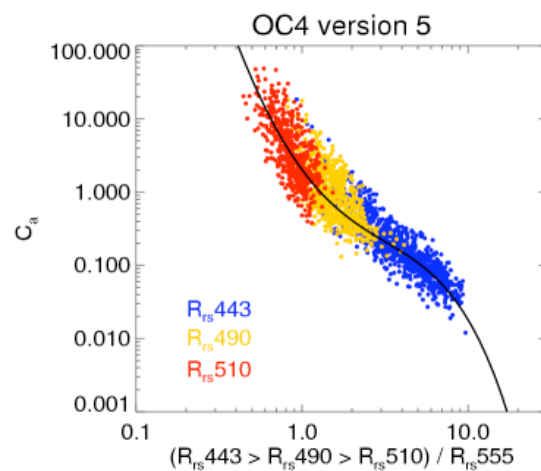
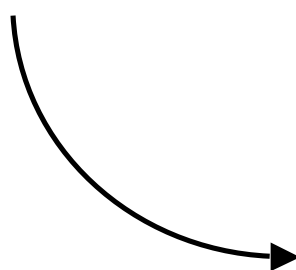
$$OC_{corr} = 10^{\left(\frac{\log_{10}(OC) - a}{b} \right)}$$

where a and b are the regression
 intercept and slope, respectively for the
 Level-2 match-up stations



In **OC-sat**, pairs of **satellite R_{rs}** and **in situ C_a** from the Level-2 match-ups are used to rederive and OC relationship ...

OC3 analog (443,490,555-nm)
linear expression, rather than polynomial



some challenges to remote sensing of coastal and inland waters:

temporal and spatial variability

- limitations of satellite sensor resolution and repeat frequency

- validity of ancillary data (reference SST, wind)

- varied resolution requirements and binning options

straylight contamination from land

non-maritime aerosols (dust, pollution)

- region-specific models required

- absorbing aerosols

suspended sediments and CDOM

- complicates estimation of $L_w(\text{NIR})$, model not a function of C_a

- complicates correction for non-uniform subsurface light field (f/Q)

- saturation of observed radiances

anthropogenic emissions (NO_2 absorption)

general processing system and analysis infrastructure:

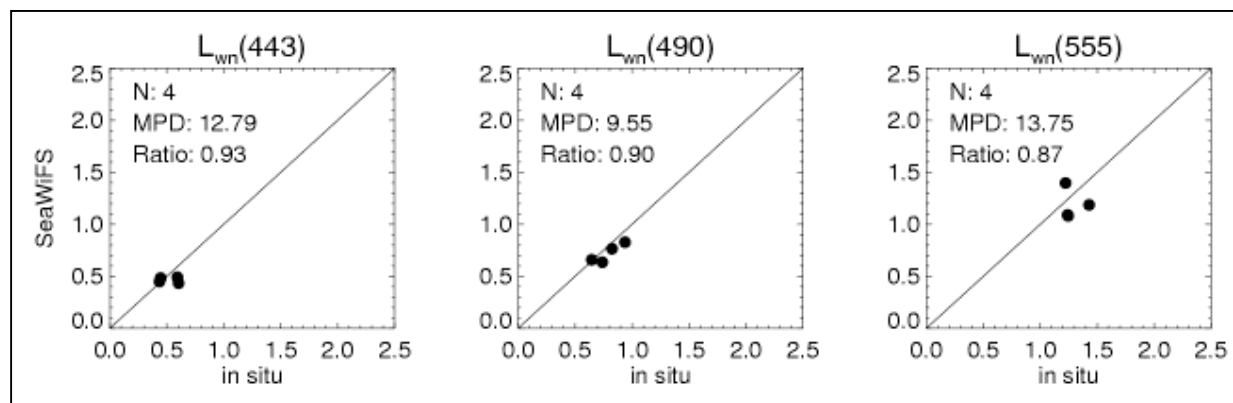
P.J. Werdell, B.A. Franz, S.W. Bailey, L.W. Harding Jr., and G.C. Feldman, "Approach for long-term spatial and temporal evaluation of ocean color satellite data products in a coastal environment," Proc. SPIE 6680, doi:10.1117/12.732489 (2007).

baseline analyses (OC4, OC3, GSM-CB) and **OC-corr** / **OC-sat** development:

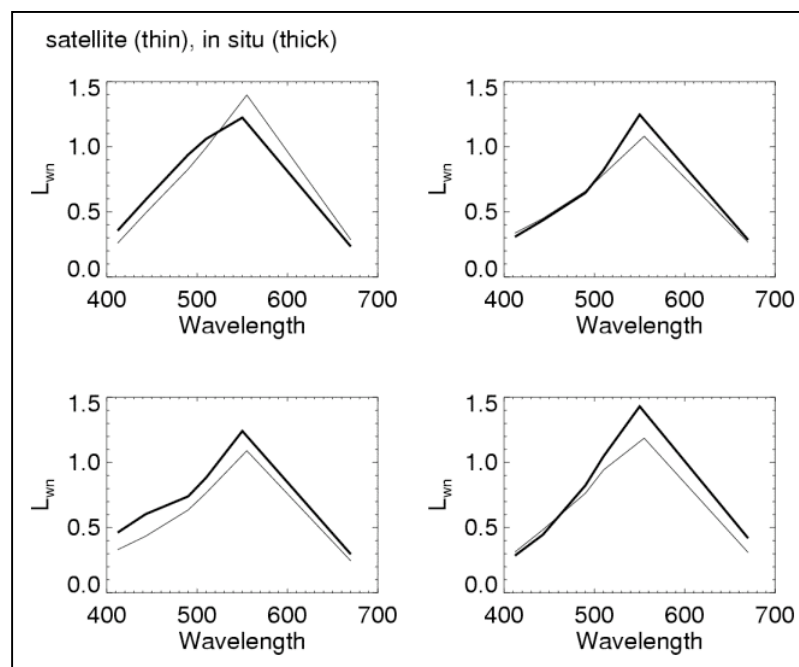
P.J. Werdell, S.W. Bailey, B.A. Franz, L.W. Harding Jr., G.C. Feldman, and C.R. McClain, "Regional and seasonal variability of chlorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Estuar. Coast. Shelf Sci., *revision submitted* (2008).



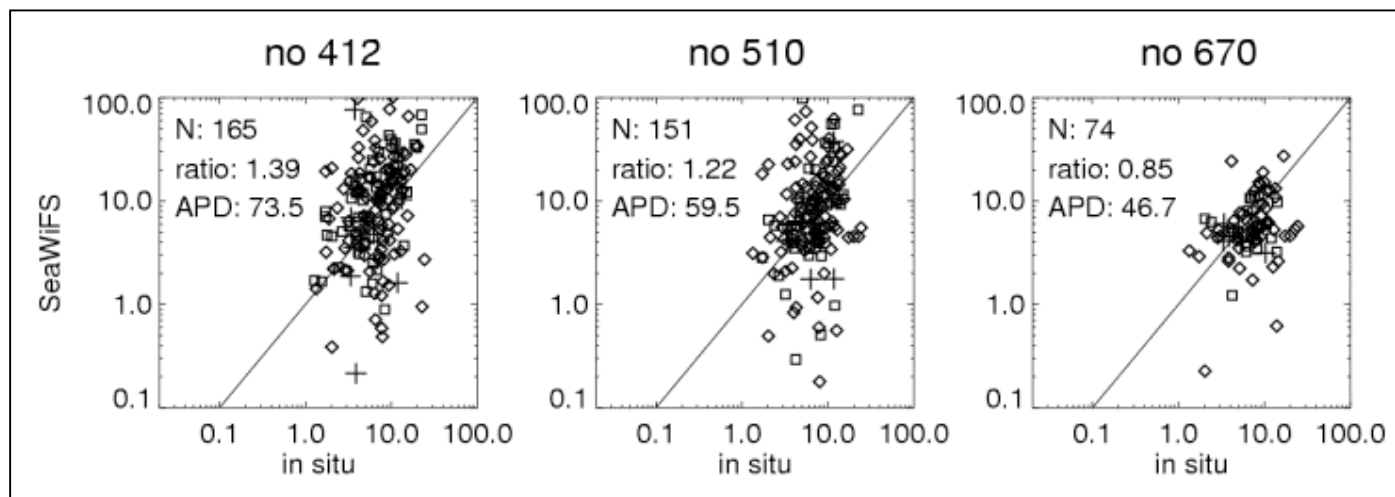
NASA Ocean Biology Processing Group ~ PJW, SSAI, 1 Aug 2008



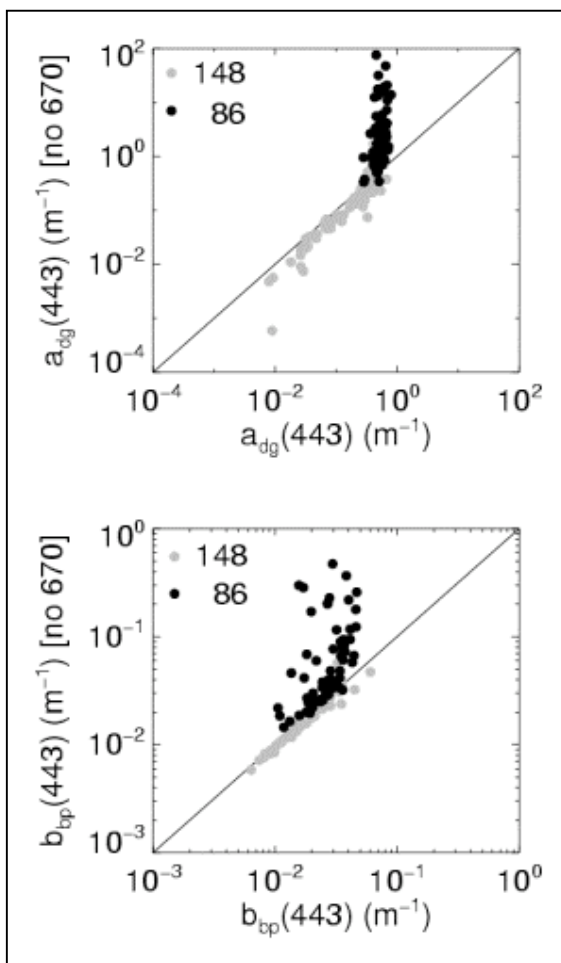
SeaWiFS Level-2
radiometric match-ups



GSM-CB sensitivity analysis - wavelength reduction



GSM-CB sensitivity analysis - wavelength reduction



semi-analytical algorithms

$$R_{rs} = g_0 \left(\frac{b_b}{a + b_b} \right) + g_1 \left(\frac{b_b}{a + b_b} \right)^2$$

$$a(\lambda) = a_w(\lambda) + a_{dg}(443) e^{-S(\lambda - 443)} + a_\phi^*(\lambda) \text{ } \textit{Chl}$$

$$b_b(\lambda) = b_{bw}(\lambda) + b_{bp}(443) \left(\frac{443}{\lambda} \right)^\eta$$

$R_{rs}(\lambda)$ from satellite(s)

S , η , g_0 , g_1 , & $a_\phi^*(\lambda)$ are constants

$a_{dg}(443)$, $b_{bp}(443)$, & \textit{Chl} are unknown